Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/271
UNITED STATES
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

SPACE TIME REACTOR DYNAMICS

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In order to extract the heat of a nuclear reactor efficiently and safely the nuclear designer should be able to calculate the detailed spatial distribution of the power generation. In principle, he should be able to calculate this distribution for all times during the reactor life, for all static and transient operating conditions, and for various postulated accidental transients. In practice, calculational tools providing this ability have not been available; instead, in design calculations the reactor is usually represented by a one- or two-dimensional model and, for the calculation of transients, often by a single spatial point.

Such methods have sufficed thus far; however, there is growing interest in more precise treatments of spatial effects both in static and dynamic calculations. Partly this is a result of the trend toward large power reactors in which spatial effects become important. In large reactors power shapes tend to show large distortions in response to small disturbances. The power shapes tend to be strongly dependent on operating conditions and fuel management policy and may oscillate spontaneously as a result of xenon feedback.

This paper assesses the significance of space-time problems in reactor design, surveys the analytical and computational tools available for their investigation, reviews pertinent experimental data, describes the new computational tools which are being planned or developed, and indicates potential means of verifying these tools through detailed reactor experiments. The discussion will classify and relate the various analytical approaches.

There are three approaches to the problem of xenon stability. The first

is the "stability in the small" approach in which one examines the linearlized equations which describe the system in the close vicinity of an equilibrium point and attempts to derive criteria for stability of this point. In the Second approach one examines large regions of the state space, possibly with methods of the Lyapunov type, in a search for limit cycles, regions of asymptotic stability, etc. Thirdly, one may attempt to compute a xenon transient in detail, observing its growth or decay. This may be done by the "brute force" method of using a diffusion-depletion code with short time steps or alternately, by using an approximate representation of the spatial dependence (as described below) followed by analog or digital treatment of the time dependence.

We may consider the calculation of general space-time transients as consisting of three segments which proceed simultaneously. The first is the solution of the neutron equations to determine the instantaneous power distribution. The second is the solution of the heat flow and coolant equations to determine the temperature and density distribution knowing the power distribution. The third segment is the calculation of the nuclear cross section, i.e. the coefficients in the nuclear equations, from the instantaneous temperature and density.

Performance of these calculations with a detailed three dimensional spatial description is out of the question at the present time and so most interest has centered on methods for approximating the spatial dependence. Here we distinguish four methods: (i) adiabatic method; (ii) higher order difference or "cell" method; (iii) nodal analysis; and (iv) modal analysis. These will be described and illustrated with sample calculations.